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**Baskett et al.**

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(54) **FORCE SENSOR FOR USE IN AN INPUT DEVICE AND METHODS FOR CONSTRUCTING AND USING THE SENSOR**

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***G06F 3/0354*** (2013.01)
***G01L 5/16*** (2006.01)
***G01L 5/22*** (2006.01)

(52) **U.S. Cl.**

CPC ............ ***G06F 3/03543*** (2013.01); ***G01L 5/165*** (2013.01); ***G01L 5/223*** (2013.01)

(58) **Field of Classification Search**

CPC ... G06F 3/03545; G06F 3/016; G06F 3/0338; G06F 3/046

USPC .................... 345/156–178; 178/18.03, 18.06; 702/41, 190; 73/862.632

See application file for complete search history.

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(57) **ABSTRACT**

The disclosure addresses a force sensor that is scalable in size and adaptable to a variety of form factors, including those suitable for use in an input device for a computer or other processing system, and in some cases including those of the configuration normally referred to as a computer mouse. The force sensor will include at least two structural members that are cooperatively attached one another as to be displaced from one another in response to a force acting upon one of the structural members. In some examples, the engagement between the two structural members will be specifically configured to allow such displacement in response to forces acting laterally on the force sensor. The force sensor will also include one or more sensing mechanisms to provide a measurement of the sensed deflection.

**19 Claims, 5 Drawing Sheets**

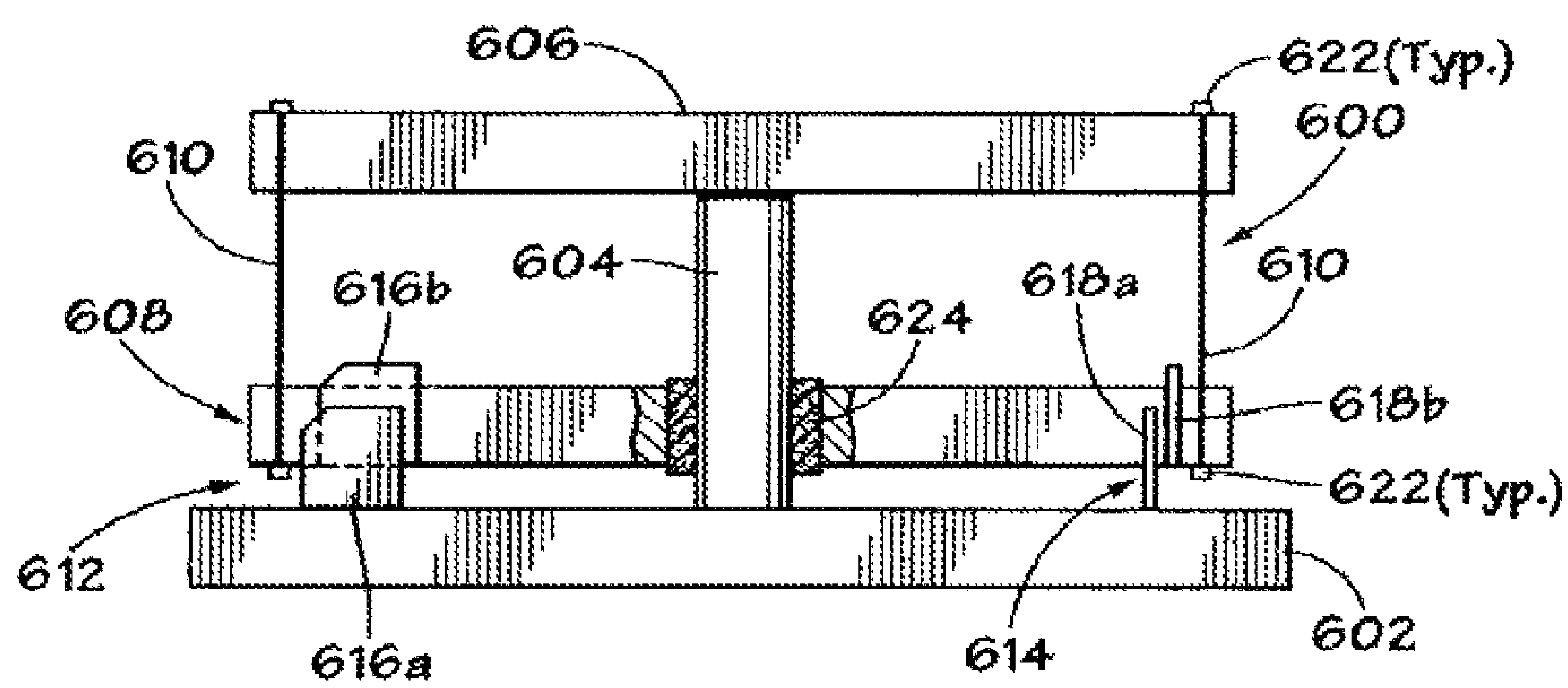

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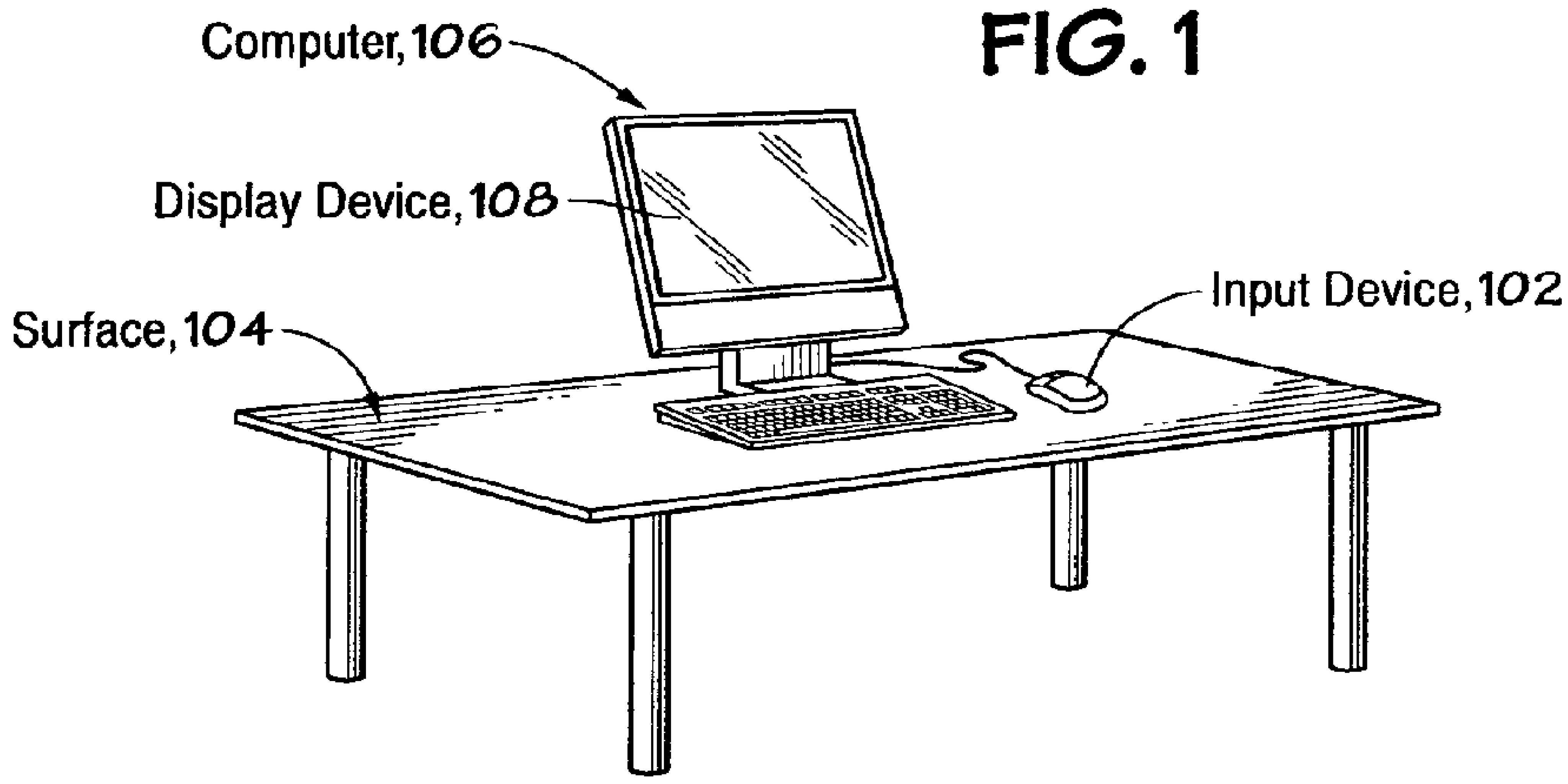
FIG. 1


Computer, 106
Display Device, 108
Surface, 104
Input Device, 102

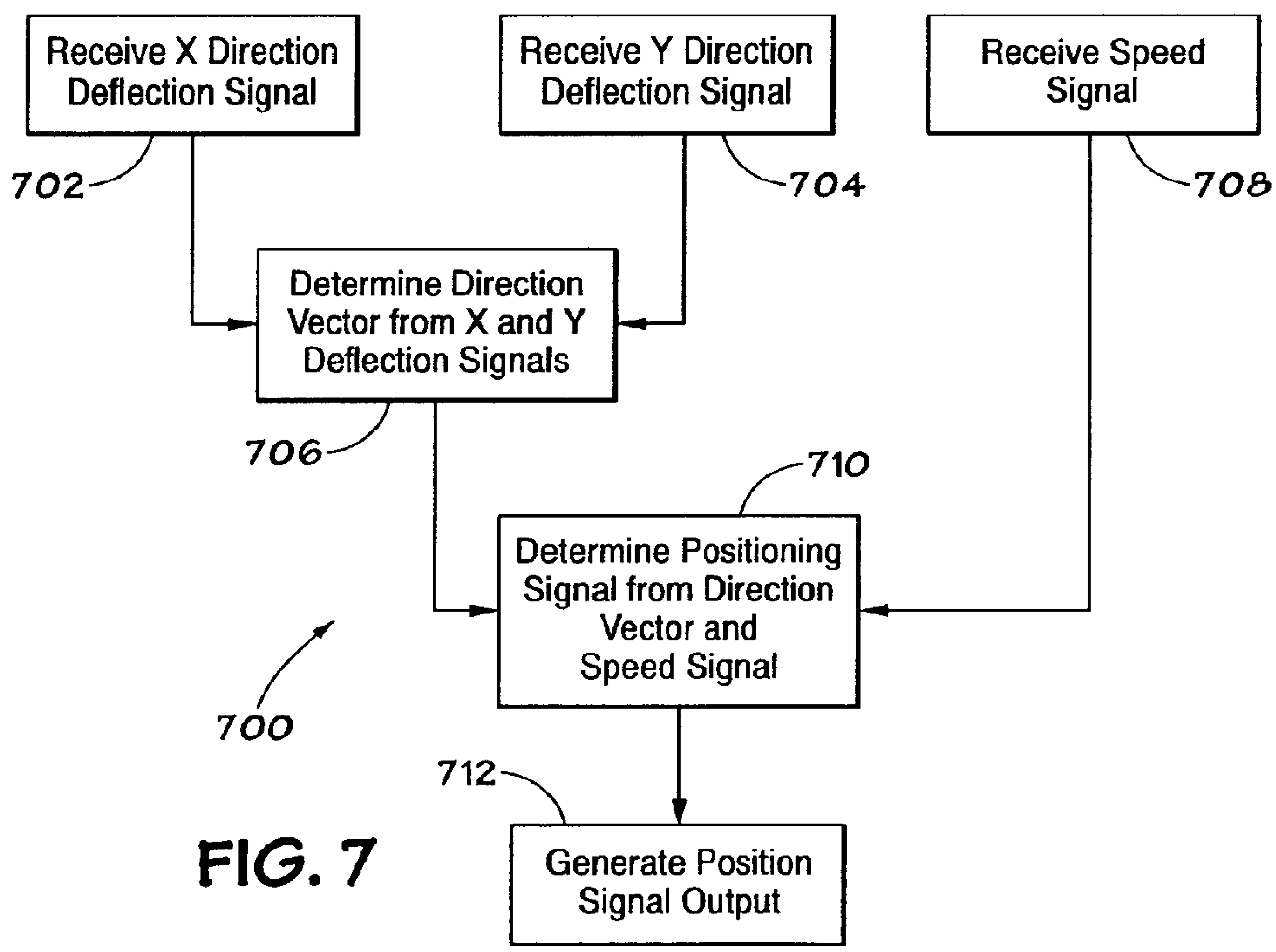

Receive X Direction Deflection Signal
702
Receive Y Direction Deflection Signal
704
Receive Speed Signal
708
Determine Direction Vector from X and Y Deflection Signals
706
710
Determine Positioning Signal from Direction Vector and Speed Signal
700
712
Generate Position Signal Output

FIG. 7

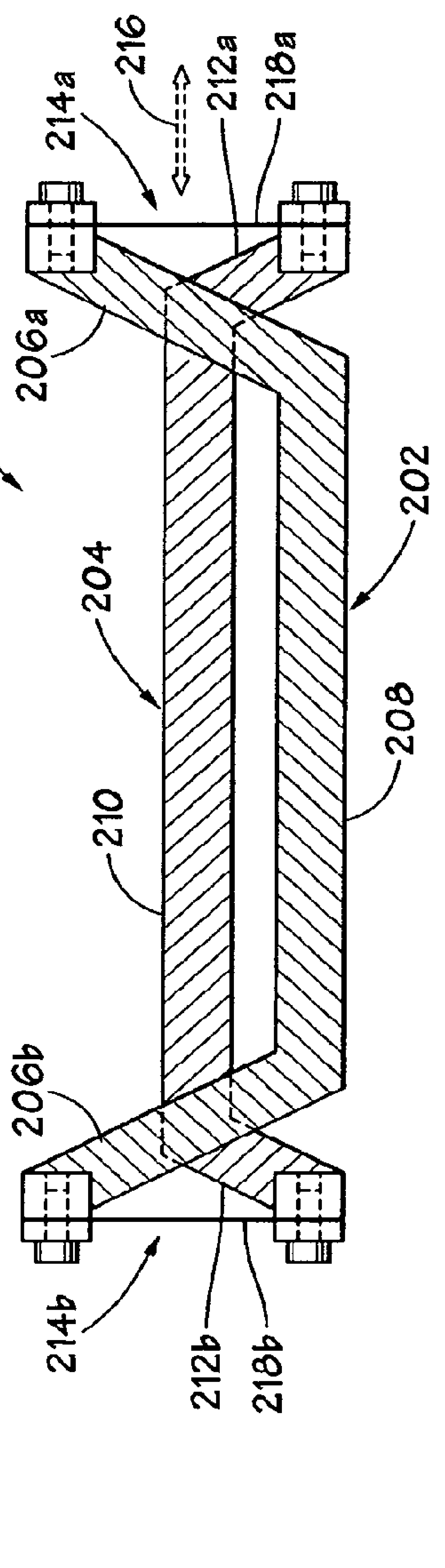

200
202
204
206a
206b
208
210
212a
212b
214a
214b
216
218a
218b

FIG. 2A

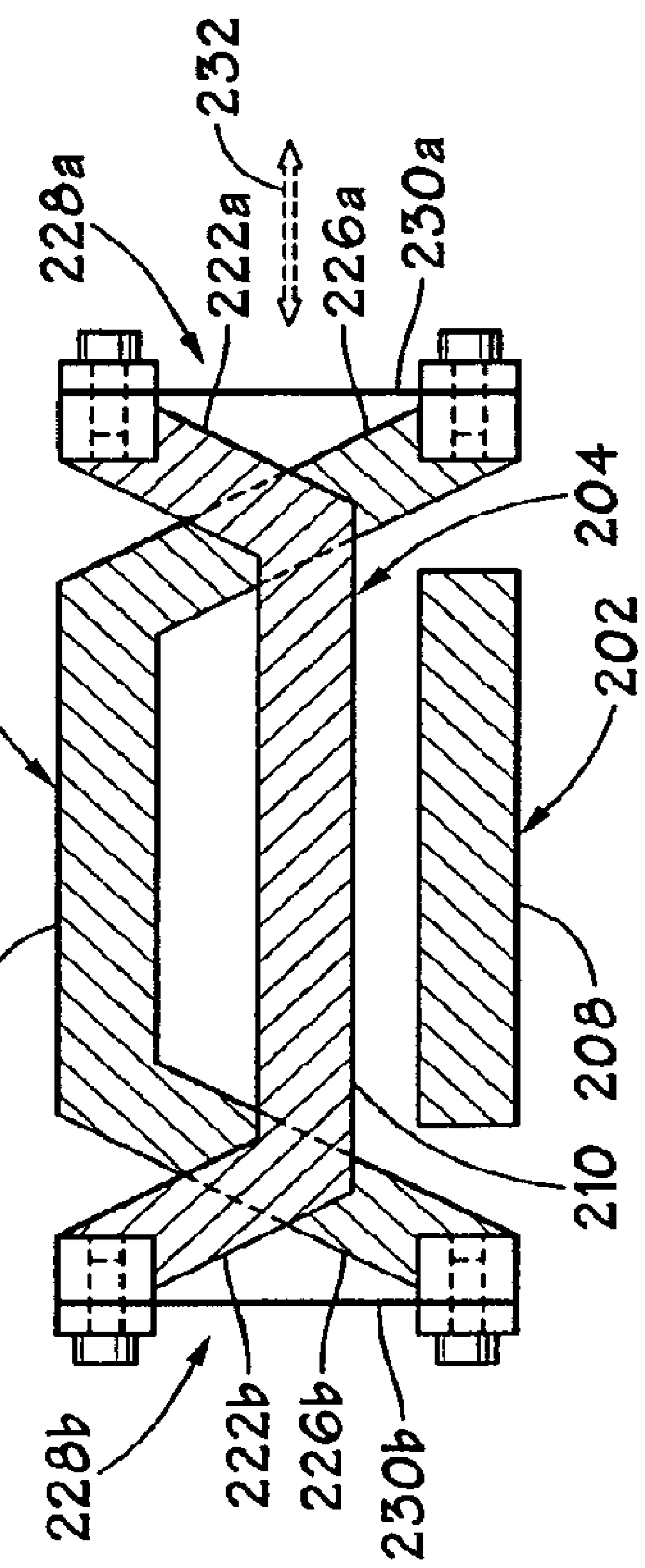
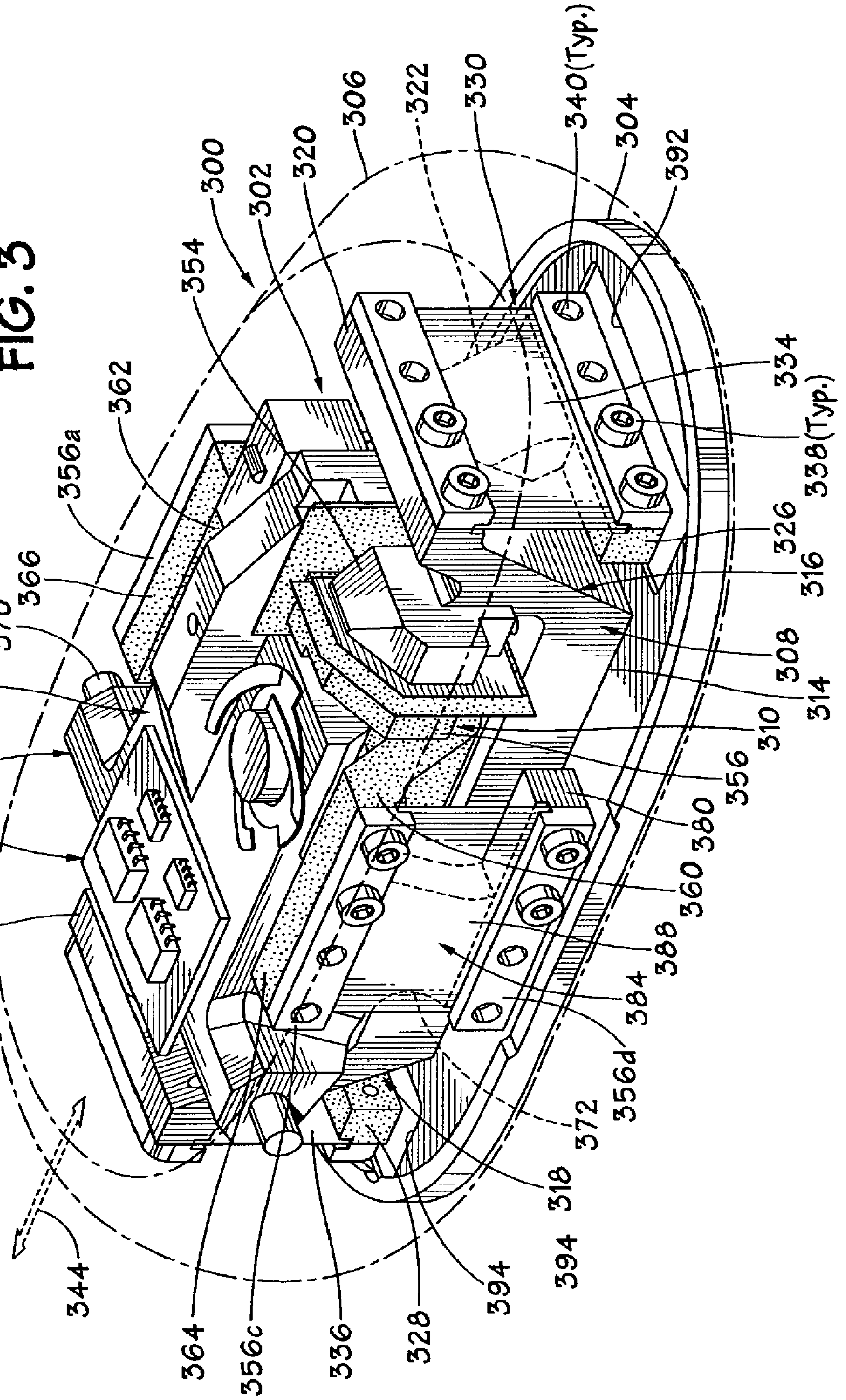
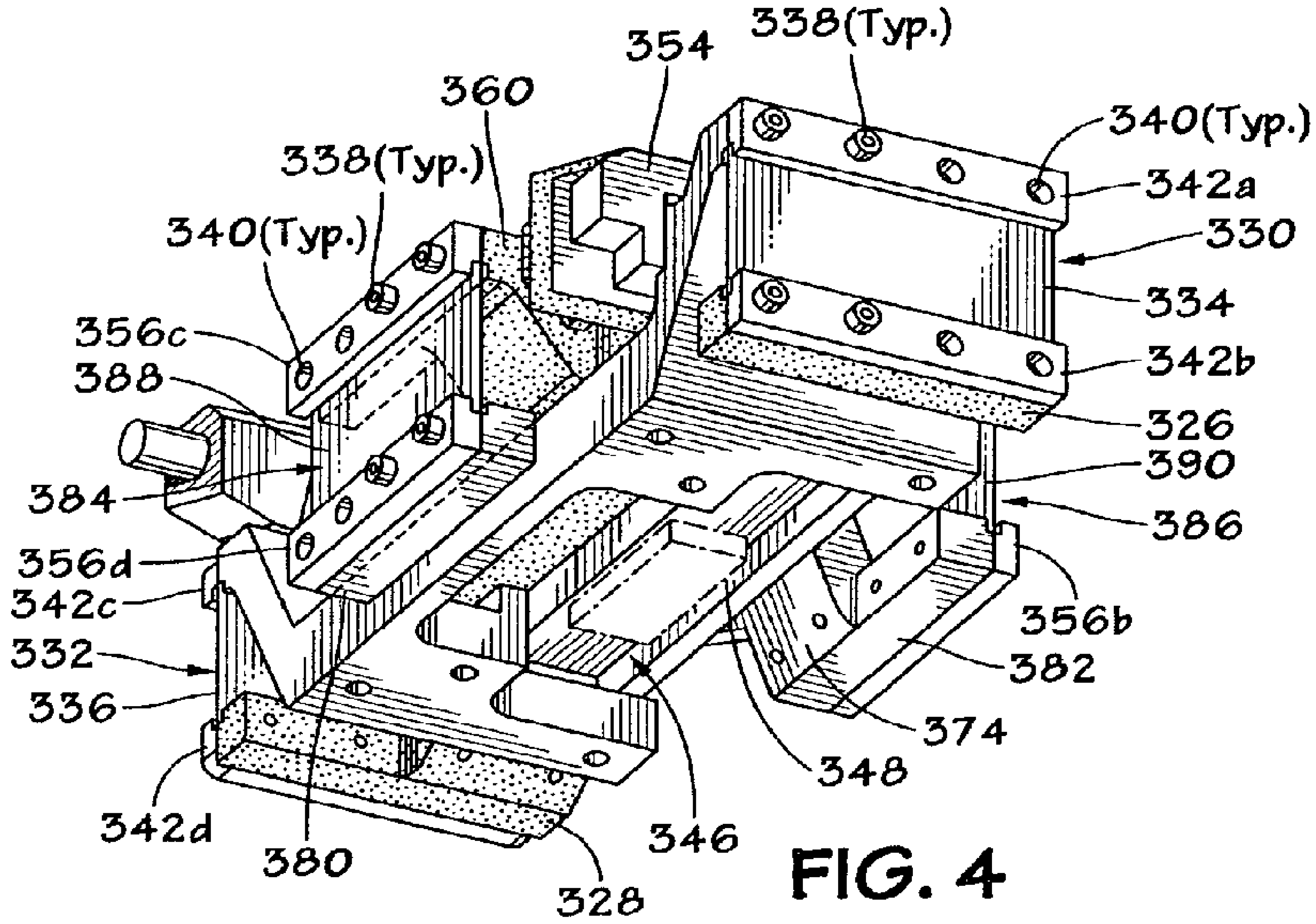

202
204
208
210
220
222a
222b
224
226a
226b
228a
228b
230a
230b
232

FIG. 2B

FIG. 3


300
302
304
306
308
310
312
314
316
318
320
322
326
328
330
334
336
338(Typ.)
340(Typ.)
344
354
356
356a
356c
356d
358
360
362
364
366
368
370
372
380
384
388
392
394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340(Typ.)
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338(Typ.)
330
340(Typ.)
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356c
342b
388
326
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384
386
356d
342c
356b
332
382
336
374
348
342d
346
380
328

FIG. 4

FIG. 5

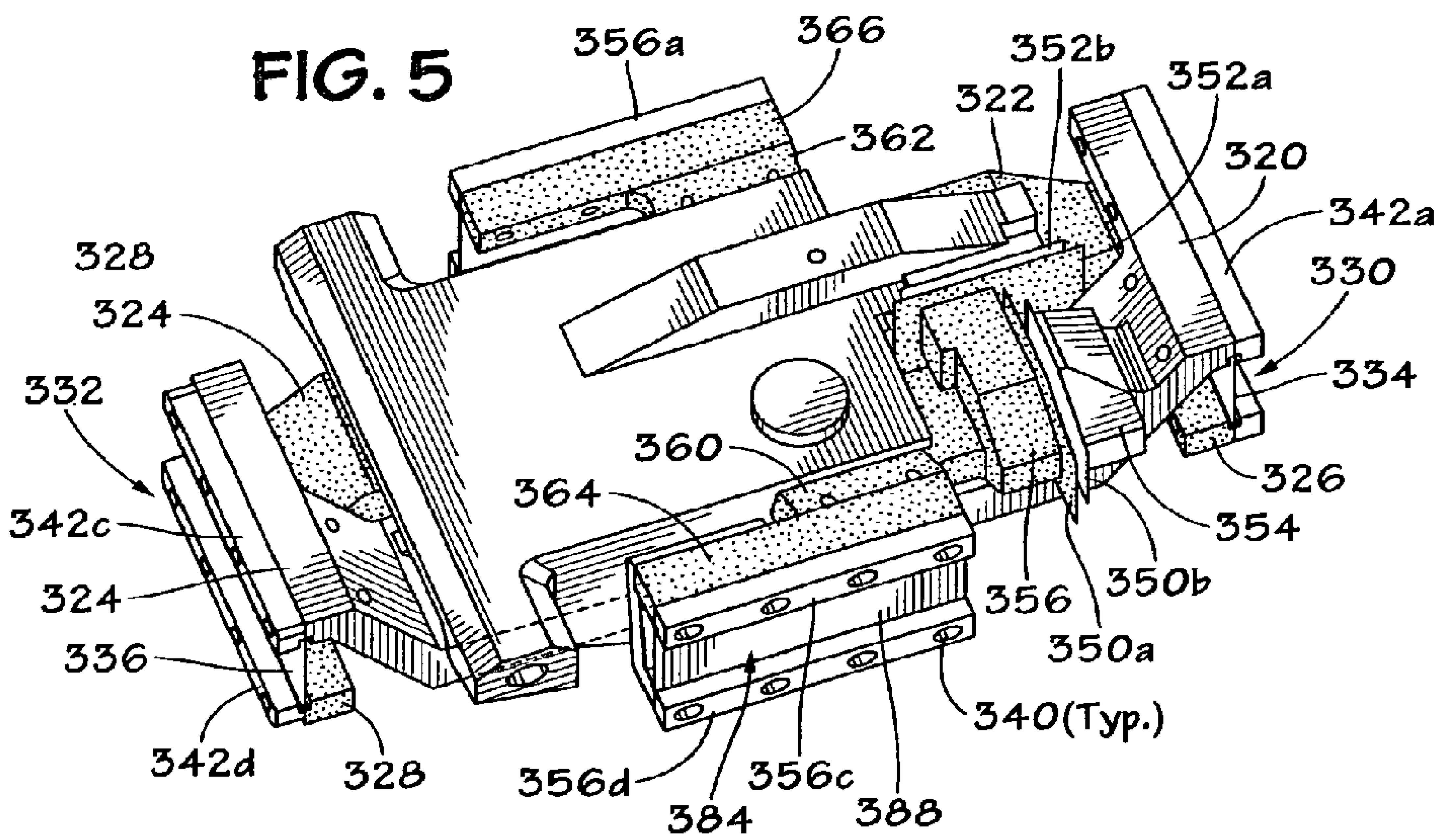

356a
366
352b
322
352a
362
320
342a
328
330
324
334
332
360
326
364
354
342c
356
350b
324
336
350a
340(Typ.)
342d
328
356d
356c
388
384

FIG. 6A

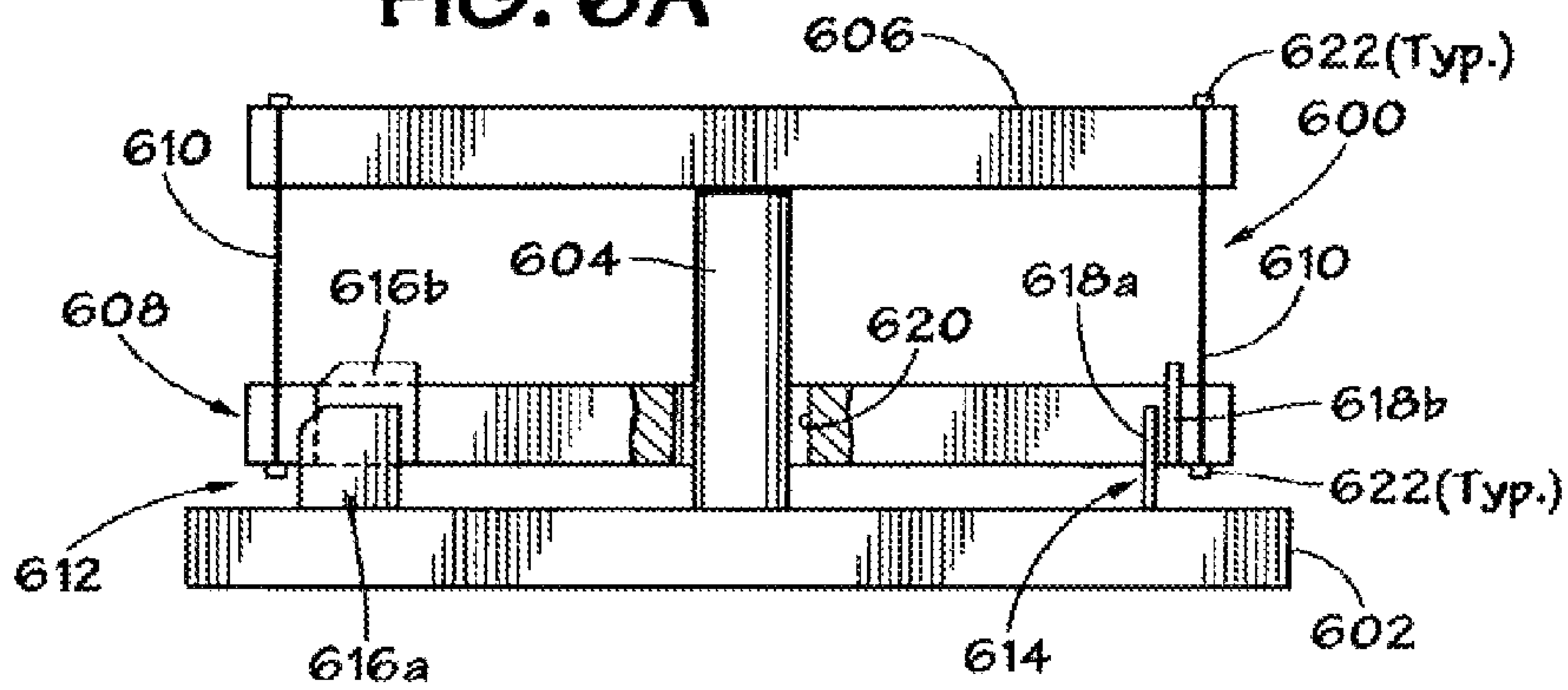



FIG. 6B

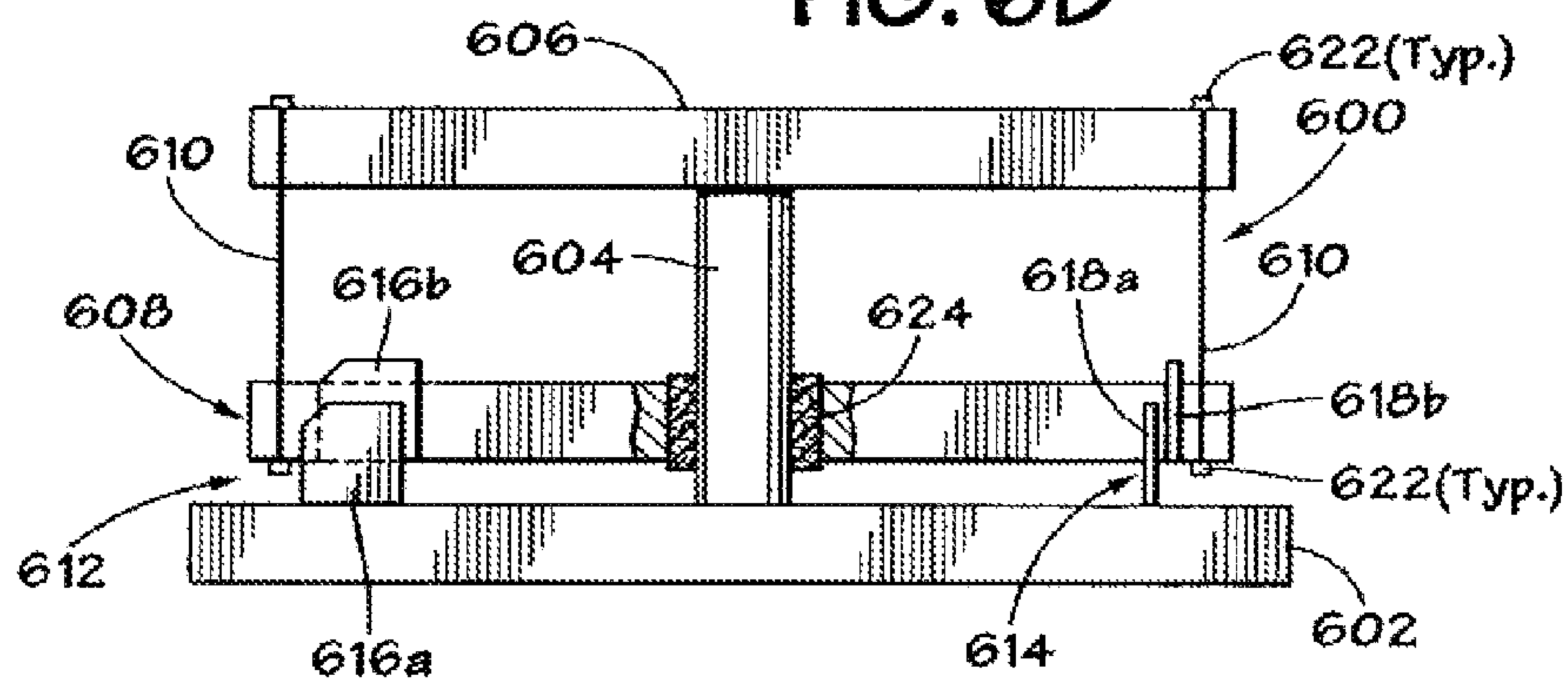
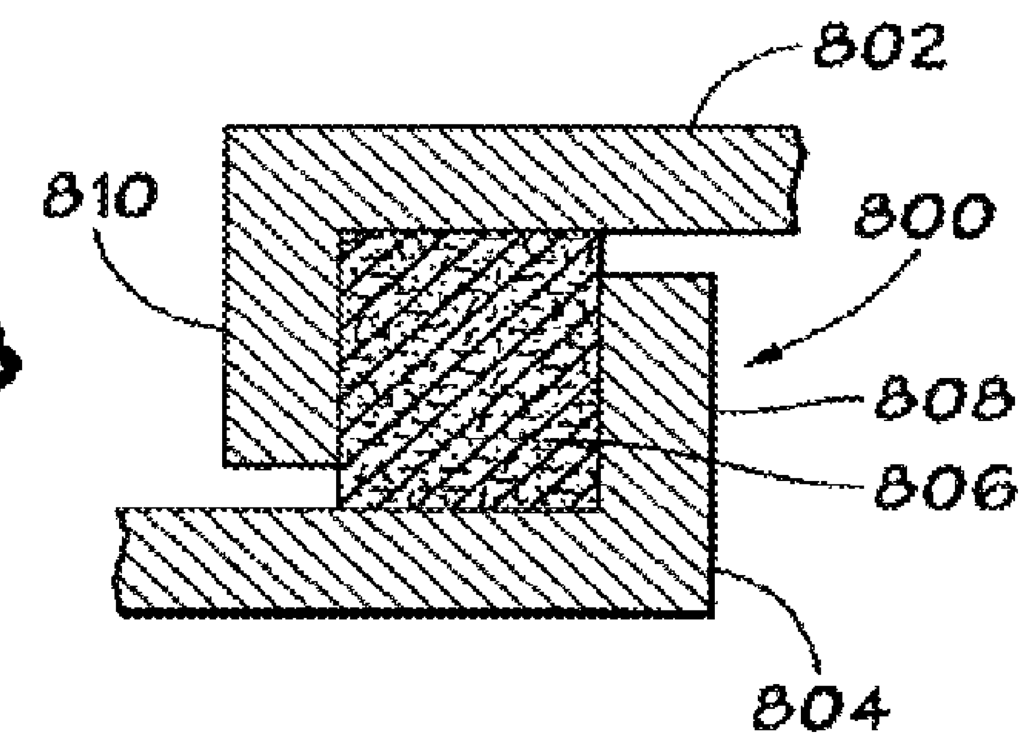



FIG. 8



# FORCE SENSOR FOR USE IN AN INPUT DEVICE AND METHODS FOR CONSTRUCTING AND USING THE SENSOR

This application is a continuation of U.S. patent application Ser. No. 12/353,732, entitled "Force Sensor for Use in an Input Device and Methods for Constructing and Using the Sensor", filed on Jan. 14, 2009, which is incorporated by reference in its entirety as if fully disclosed herein.

## BACKGROUND OF THE INVENTION

The present invention relates generally to force sensors, and more specifically relates to improved force sensors sized and configured to be suitable for inclusion in a hand-held device, and to methods for constructing such input devices; and further to methods for sensing deflection in an input device as an indictor of direction of movement of the input device.

Input devices for computers and other processing systems, such as those typically referred to individually as a computer "mouse," are well-known for use to provide data used to incrementally move an indicator such as a cursor on a display, to control the processing system. Many such "mice" operate through direct communication with an external surface. Well-known examples of such mice include various devices that operate through physical contact of a caged ball rolling on a support surface to provide an indication of movement through detection of the movement by orthogonally-arranged sensors detecting relative X-Y directional components of the ball movement, as it rolls in any direction relative to the surface. Similarly, mice are well-known which utilize an optical sensor to detect movement of the device relative to a support surface.

Input devices such as a computer mouse have recently been proposed by persons employed by the assignee of the present application, that function in the absence of the described physical or optical interaction with a support surface. These recently-proposed input devices operate using other types of sensors, as will be described in more detail later herein, without the need for such mechanical contact or optical elements One example of such an input device is described in U.S. application Ser. No. 12/242,343, filed Sep. 30, 2008, and entitled "Method and Apparatus for Operating an Input Device," the specification of which is hereby incorporated herein by reference for all purposes. These recently-proposed input devices may be in the form of conventional devices such as those normally thought of as "mice." However, these input devices may also be of such other configurations as may be desired in any particular context to provide directional and/or positional input.

One example of such an input device utilizes a force sensor assembly to detect lateral force applied to the input device, such as by a user. This force detection is preferably made relative to at least two intersecting axes to provide resolution of the direction of movement in a single plane, i.e., relative to a supporting surface. In these recently-proposed input devices, a second sensor assembly is used to provide a measure of the speed of the movement. In some examples, a vibration sensor is used to provide this speed measure. Thus the two sensor assemblies together provide measures of the direction and speed of movement of the input device that can be combined to provide positioning data based on the movement of the mouse.

In these recently-proposed devices, although virtually any type of force sensor able to detect loading applied relative to at least two different axes could be utilized, optimal performance is believed to be best obtained by a force sensor constructed to withstand the rigors of use over an extended time period, and by potentially by multiple persons with a wide range of operating tendencies. While at the same time, the force sensor will preferably fit within a conventionally-sized input device form factor, and is preferably a device that may be relatively straightforward to manufacture without undue expense.



## SUMMARY OF THE INVENTION

The present invention includes a force sensor adaptable to a variety of input device form factors, and particularly to form factors for hand held use. For the examples described herein, the input device will be a computer mouse, and thus the described force sensor is one sized and configured for use within a spatial envelope suitable for that type of hand-operated input device. The present invention, in part, provides a force sensor configured to provide signals representative of relative displacement between two components of the input device.

In one example of the invention, the inventive input device will include at least two structural members, such as external housing members forming the outer "shell" of a mouse that may be assembled to provide a unit wherein the two structural members form a single unit, although one in which the two structural members may be displaced a small dimension relative to one another, such displacement being possible relative to at least two intersecting axes. In one example, the force sensor will be constructed as a discrete assembly that may be mounted to engage both structural members (such as the example housing components) and to provide signals relative to any displacement between the structural members.

In one embodiment of force sensor as will be described herein, the force sensor will include a plurality of frame members held in general relation proximate one another, but with relative displacement allowed by flexure elements extending between the frame members. One or more of the frames will carry force or position sensors arranged to detect the above-described displacements when they occur. In some examples, these position sensors will include capacitance sensors providing varying signals in response to varying proximity between two plates in spaced relation to one another. More details on these examples, as well as on additional structural and operational variations that may be implemented in various examples of the inventive subject matter are provided in the description that follows.

## BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1** depicts a representation of an input device in association with a computer in one common operating environment and configuration.

FIGS. **2**A-B depicts a schematic representation of one example of a force sensor as will be described herein, depicted in only a partial view in FIG. **2**A; and depicted in a complete view and rotated 90 degrees in FIG. **2**B.

FIG. **3** depicts an example configuration for an input device for processing system, and including a force sensor in one example configuration.

FIG. **4** depicts the force sensor from the input device of FIG. **3**, depicted from a lower elevation perspective.

FIG. **5** depicts the force sensor from the input device of FIG. **3**, depicted from an aerial perspective.

FIGS. **6**A-B depict an alternate configuration for a force sensor in accordance with the present invention, depicted in

FIG. **6**A from a side view, and partially in vertical section; and in a further alternative configuration in FIG. **6**B.

FIG. **7** depicts a flow chart identifying one example of a method for operating an input device utilizing a force sensor in accordance with the present invention.

FIG. **8** depicts an isolated view of an alternative configuration for forming a flexible connection between structural members of a force sensor in accordance with the present invention.

## DETAILED DESCRIPTION OF PREFERRED EMBODIMENTS

The following detailed description refers to the accompanying drawings that depict various details of examples selected to show how the present invention may be practiced. The discussion addresses various examples of the inventive subject matter at least partially in reference to these drawings, and describes the depicted embodiments in sufficient detail to enable those skilled in the art to practice the invention. Many other embodiments may be utilized for practicing the inventive subject matter than the illustrative examples discussed herein, and many structural and operational changes in addition to the alternatives specifically discussed herein may be made without departing from the scope of the inventive subject matter.

In this description, references to "one embodiment" or "an embodiment," or to "one example" or "an example" mean that the feature being referred to is, or may be, included in at least one embodiment or example of the invention. Separate references to "an embodiment" or "one embodiment" or to "one example" or "an example" in this description are not intended to necessarily refer to the same embodiment or example; however, neither are such embodiments mutually exclusive, unless so stated or as will be readily apparent to those of ordinary skill in the art having the benefit of this disclosure. Thus, the present invention can include a variety of combinations and/or integrations of the embodiments and examples described herein, as well as further embodiments and examples as defined within the scope of all claims based on this disclosure, as well as all legal equivalents of such claims.

For the purposes of this specification, a "processor-based system" or "processing system" includes a system using one or more processors, microcontrollers and/or digital signal processors or other devices having the capability of running a "program," (all such devices being referred to herein as a "processor"). A "program" is any set of executable machine code instructions, and as used herein, includes user-level applications as well as system-directed applications or daemons. Examples of processing systems include communication and electronic devices such as cell phones, music and multi-media players, and Personal Digital Assistants (PDA); as well as computers, or "computing devices" of all forms (desktops, laptops, servers, palmtops, workstations, etc.).

Referring now to FIG. **1**, therein is depicted an input device **102** as one example of many possible configurations that may be used to implement the present invention. Input device **102** is connected to a processing system, in this example, a desktop computer **106** having a display device **108** associated therewith, in one example of an operative configuration. Input device **102** and computer **106** are both supported by a surface **104**, depicted here as a tabletop. In this example, input device **102** is a computer mouse that will determine positioning information (including direction and speed of movement information) primarily in response to sliding movement of input device **102** relative to supporting surface **104**.



Referring now to FIGS. **2**A-B, the figures schematically depict, in highly idealized representation, one example of a force sensor **200** in accordance with the present invention. This idealized schematic representation is used to illustrate the fundamental principles of construction and operation of one example configuration to be described in more detail later herein. Referring now particularly to FIG. **2**A, the figure shows a schematic representation of a first frame member **202** and a second frame member **204**. Frame member **202** includes a pair of angled arms **206***a*, **206***b*, where each arm **206***a*, **206***b* is inclined generally upwardly relative to a respective opposing end of a central web portion **208**. Similarly, second frame member **204** includes a central web portion **210** positioned generally above central web portion **208** of first frame member **202**. Second frame member **204** includes a pair of angled arms **212***a*, **212***b* inclined generally downwardly from respective opposing ends of central web portion **210**.

First and second frame members **202**, **204** are coupled to one another by mechanism that allows relative deflection (or movement) between the two frame members. In this example, that movement is generally restrained to be primarily along a single axis. However, configurations where movement is facilitated relative to multiple axes are contemplated. In various configurations, this deflection mechanism may be in the form of either a coupling material or a mechanical assembly coupling the two members. The deflection mechanism may include either a single assembly or a plurality of assemblies. In the depicted example of FIG. **2**A, the deflection mechanism is provided by first and second flexure assemblies **214***a*, **214***b* coupled between proximate pairs of angled arms **206***a*, **212***a* and **206***b*, **212***b* of first and second frame members **202**, **204**.

Flexure assemblies **214***a*, **214***b* may be formed of a variety of materials and conformations so long as they allow deflection within a limited range between the two frame members **202**, **204**. For example, the deflection within a force sensor such as that suitable for use within a computer mouse will preferably be deflection of less than 1 mm, and more preferably within the range of 0.1 to 0.5 mm; and in some examples, less than approximately 0.1 mm. In most use situations, the mouse will be exposed to loads of less than about 250 grams. Many possible configurations may be envisioned for flexure assemblies **214***a*, **214***b*. For example, flexure assemblies **214***a*, **214***b* could be formed of a material that would be generally solid, but be sufficiently deformable to allow the described deflection. As just one example of such material, a flexible elastomer, such as a silicon-based elastomer could be used.

In the example of FIG. **2**A, the described configuration of first and second frame members **202**, **204** is specifically suited for use with a generally rigid but flexible element in each flexure assembly **214***a*, **214***b*. For example, flexible elements formed of various suitable plastics, metals or other compounds can be used to form, in essence, a spring extending between the two frame members **202**, **204**. In one example of the invention, as will be described in more detail later herein, each flexure assembly will include a flexible member **218***a*, **218***b* of this type, formed of a flexible metal band. One advantage of using a flexible member **218***a*, **218***b* such as a metal band is that when such a structure is supported across its upper and lower surfaces, then the member is typically flexible generally along an axis extending laterally and generally in parallel to the support locations; and thus in such a structure each flexible member allows relative movement primarily along an axis extending perpendicular to that to that flex axis, as depicted generally at **216**. In the embodiment depicted in

FIG. **2**A, the flexible members **218***a*, **218***b* are generally planar and generally parallel in a vertical orientation when in an "at rest" orientation, and thus the axis of movement extends generally perpendicular to not only the flex axis but also to the plane of the material when in the "at rest" position. It should be readily understood however that the flexible members **218***a*, **218***b* are not required to be either vertical or parallel to one another.

Referring now to FIG. **2**B, the figure schematically depicts the assembly of FIG. **2**A, rotated 90 degrees, and as viewed through a partial vertical cross-section, and with a third support member **220** added to assembly **200** of that figure. The depiction is of a vertical slice only, and for clarity no attempt is made to show surfaces that would be visible in the background in a true vertical section. This view thus depicts that second support member **204** also includes a second pair of angled arms **222***a*, **222***b* extending generally upwardly relative to central web portion **210**. Thus, second support member **204** includes a first pair of arms **212***a*, **212***b* extending generally downwardly to a first side of central web portion **210** (shown in FIG. **2**A), and a second pair of arms **222***a*, **222***b* extending generally upwardly to a second side of central web portion **210**. As is apparent from FIGS. **2**A-B, the terms "upwardly" and "downwardly" are not intended to suggest truly opposite, or 180 degree offset orientation; but only to designate the relative orientation relative to the central web portion of the support member in question.

The newly-depicted third support member **220**, as with first and second support members, again includes a central web portion **224** and a pair of angled arms **226***a*, **226***b* extending from respective ends of central web portion **224**. In this example, the arms extend generally downwardly or below central web portion **224**. As previously described relative to FIG. **2**A, a pair of flexure assemblies **228***a*, **228***b* are coupled between proximate pairs of angled arms **222***a*, **226***a* and **222***b*, **226***b* of second and third frame members **204**, **220**. Flexure assemblies **228***a*, **228***b* may be constructed similarly to first and second flexure assemblies **214***a*, **214***b*, as described above. However, such similar construction is not required. Where each flexure assembly **228***a*, **228***b* includes a flexible member **230***a*, **230***b* similar to those described in reference to FIG. **2**A, then the permitted deflection between second support member **204** and third support member **220** will be generally along axis **232** which extends generally perpendicular to axis **216**, the axis of the permitted deflection between first support member **202** and second support member **204**.

Thus, as is apparent from the above discussion, FIGS. **2**A-B schematically depicted a stacked structure in which deflection of each adjacent pair of support members is restricted primarily to one of two orthogonal axes. It should also be apparent that the stacked structure could include additional support members such that the deflection in either direction could be permitted by a completely independent structure rather than through the shared structure in which second support member **204** is coupled to both the lowermost first support member **202** and the uppermost second support member **220**. However, the shared structure, as depicted, is believed to offer some advantages, such as requiring reduced vertical space, and is thus preferable for applications where vertical dimension is a possible consideration.

The above-described idealized schematic representation identifies the fundamental structural principles utilized in the device depicted in FIG. **3**, discussed below. The above-described schematic representation does not identify any sensors or components thereof to provide signals representative of any translational displacement that occurs between support members connected through flexure assemblies. As will be identified in the discussion of FIG. **3**, components of such sensors will preferably be attached to the interconnected support members.

Referring now to FIG. **3**, the figure depicts a mouse assembly indicated generally at **300**, including a force sensor assembly, indicated generally at **302**. Mouse assembly **300** includes two structural members that cooperatively form the external housing of the mouse, lower plate **304** and upper shell **306**, depicted in phantom representation. The following description may also be considered in reference to FIGS. **4** and **5**, which depict force sensor assembly **302** from opposing elevation perspectives. FIG. **4** depicts force sensor assembly **302** from a lower elevation view, thereby viewing force sensor assembly **302** looking upwardly toward lower-facing surfaces; and FIG. **5** depicts force sensor assembly **302** from an upper elevation view looking generally downwardly, from a side viewing point.

The structural members of force sensor **302** that correspond in general function to the three structural members **202**, **204**, **220** of FIG. **2**, will be referred to in relative positional terms as a "lower wing **308**," a "middle wing **310**," and an "upper wing **312**." The description of these three components in terms of relative position is not intended to suggest that components need necessarily be placed in that same vertical orientation, or in any vertical orientation whatsoever. Similarly the use of the term "wing" is not used to in any way describe or suggest any shape or function to the identified structures beyond that otherwise expressly described, but is used only to provide a nomenclature that improves the clarity of the description in view of the relative complexity of the depicted configurations of the various components in force sensor assembly **302**. For clarity in the Figures, middle wing **310**, as well as a two capacitor plates carried by the wing (**350***a*, **350***b*) have been depicted with a surface texture, denoted by stippling of those parts. Such surface texture is not necessarily a desirable feature of the device, but is used solely to assist in distinguishing between the complexly-shaped components assembled in FIGS. **3**-**5**.

Lower wing **308** includes a central web portion **314** with upwardly extending arms, indicated generally at **316** and **318**. Lower wing **308**, like middle wing **310** and upper wing **312**, will preferably be constructed of a material that will be generally rigid under the conditions to which the assembly is subjected. For example, metals, such as cast aluminum, forged steel, or metal injection molded (MIM) steel may be used. However, composite materials, such as for example, a glass-filled plastic, might also be used. As can best be seen in FIG. **5**, each arm **316**, **318** terminates in a laterally extending upper support bar **320**, **322**, respectively. Similarly, middle wing **310** includes a first pair of downwardly extending arms, indicated generally at **322** and **324** (see FIG. **5**). Each of these middle wing downwardly extending arms **322**, **324** terminates in a respective laterally extending lower support bar **326**, **328**. As adjacent pairs of lower wing arms **316**, **318** and middle wing arms **322**, **324** cross past one another, laterally extending upper support bars **320**, **322** (of lower wing **302**) and laterally extending lower support bars **326**, **328** (of middle wing **304**) are each wider than the respective arm from which they extend. Each pair of proximately adjacent support bars **320** and **326**, and **322** and **328** supports a respective flexure assembly, indicated generally at **330** and **332**.

Flexure assemblies **330**, **332** each preferably include a flexible element coupled between each respective pair of supports to allow a limited degree of translational deflection between the two wings to which the flexure assemblies are attached. Additionally, in some examples as depicted here, it is preferable that each flexure assembly provides some degree of resistance to such translational deflection; and again in some examples, it is preferable that each flexure assembly be capable of providing some degree of relative structural support between the wing members to which it is attached. Accordingly, to depict a device in which these various optional capabilities are implemented, the depicted flexure assemblies **330**, **332** comprise a flex band **334**, **336** formed of a generally stiff but resilient material. In this example, this material is a metal band formed of spring steel, having a thickness of approximately 0.04 inch; and in this one example, having an area of approximately 0.6 square inch. The use of these metal bands in flexure assemblies **330**, **332**, as depicted in this example, offers the advantage of facilitating deflection, while avoiding bearings or sliding surfaces that would introduce friction. Force sensors constructed in the manner of the depicted example therefore offer the advantage of sensitivity to movement with minimal hysteresis. Although many mounting systems for flex bands **334**, **336** may be envisioned, in the depicted example, flex bands **334**, **336** are mounted to each support bar by a mounting bar **342***a*, **342***b*, **342***c*, **342***d* that engages the exterior surface of each flex band **334**, **336** and which is bolted (by a plurality of bolts indicated typically at **338** extending through apertures, indicated typically at **340**) to a respective support bar. In this example, recesses **392**, **394** have been provided in bottom plate **304** to assure freedom of movement of the lower end of each flex band **334**, **336**.

As described in reference to FIG. **2**, because flex bands **334**, **336** are metal, and are supported along their upper and lower surfaces between a respective support bar and mounting bar, there is some resistance to torsional deflection. This construction of flex bands **334**, **336** thereby contributes to maintaining a generally fixed lateral alignment between lower wing **308** and middle wing **310**, while allowing a generally longitudinal deflection (extending through the longer axis **344** through force sensor assembly **302**, as depicted). Also as previously mentioned in reference to FIG. **2**, although flex bands **334** and **336** are each disposed in spaced generally parallel and vertical relation, that orientation is a design choice, and other orientations could readily be used, as will be apparent to those skilled in the art.

As can best be seen in FIG. **4**, in this example, central web portion **314** of lower wing **308** is not uniformly contiguous, but defines a recess, indicated generally at **346**. Recess **346** is provided in this example as a convenient location within which other components may be mounted within mouse assembly **300**. For example, another sensor, such as a vibration sensor, indicated in phantom representation at **348**, may conveniently be placed within recess **346**.

In the example configuration of mouse assembly **300** and force sensor **302**, a measurement of deflection between lower wing **308** and middle wing **310**, and also between middle wing **310** and upper wing **312**, will be made through use of electrical sensors, preferably in the form of capacitance sensors. The visible physical components of each of these capacitance sensors are respective pairs of capacitor plates at **350***a*, **350***b*, and at **352***a*, **352***b*. Capacitor plates **350***a*, **350***b*, are used to provide a measurement that may be used to generate a signal representative of deflection between lower wing **308** and middle wing **310**; while capacitor plates **352***a*, **352***b* are used to provide a measurement that may be used to generate a signal representative of deflection between middle wing **310** and upper wing **312** (which, as is apparent from the discussion of FIG. **2** will be along a lateral axis extending generally perpendicular to longitudinal axis **344**). Accordingly, capacitor plate **350***b* is mounted on an extension **354** from arm **316** of lower wing **308**; while capacitor plate **350***a* is mounted to a support **356** formed as a portion of middle wing **310**. Similarly, capacitor plate **352***a* is also mounted to support **356** of middle wing **310**, but to a surface extending generally perpendicular to that upon which capacitor plate **350***a* is mounted.

Preferably, when all wings are in an "at rest" position, capacitor plate pairs **350***a*, **350***b* and **352***a*, **352***b* will be spaced apart a sufficient distance to accommodate the desired range of deflection while providing the necessary resolution of deflection through capacitance change. In a configuration as described herein, with a deflection range of approximately 0.03 inch, a spacing between approximately 0.035 to 0.05 inch may be used, with a spacing of approximately 0.4 inch being preferred. Because the capacitance sensors formed using capacitor plates **350***a*, **350***b* will be used to identify a relatively small deflection and to provide a quantitative measurement of that deflection, and because reasonable precision is desired, it can be seen that one plate of each pair of capacitor plates (**350***b*, **352***b*) is sized smaller than the corresponding plate with which it interacts (**350***a*, **352***a*). This sizing difference helps to avoid edge effects between the plates that could otherwise diminish the accuracy of the measurements. Capacitor plates **350***a*, **350***b* will be in electrical communication with electronic circuitry, as indicated at **358**. The electrical configuration of the capacitance sensors may be achieved in a conventional manner, as known to those skilled in the art. Electronic circuitry **358** may also include such processors and other components as may be used to implement some or all of the processing functions described herein, for example, those functions described in reference to the flow chart of FIG. **7**.

This description will now further address the connections between middle wing **310** and upper wing **312**. In a manner similar to that depicted in reference to the schematic representation of FIG. **2**, middle wing **310** further includes a pair of relatively upwardly extending arms **360**, **362**, which extend generally perpendicular to the direction of downwardly extending arms **322**, **324**, thereby extending to the relative "sides" of force sensor assembly **302**. Again, each arm **360**, **362** terminates in a respective support bar **364**, **366**.

As can be seen from the figures, upper wing **312** preferably extends between the two upwardly extending arms **360**, **362** of middle wing **310**, and thus extends generally above and along lower wing **308**. In this example, upper wing **312** is coupled in laterally movable relation to the wings below it, and in pivoting relation to upper shell **306**, such as through a pivot connection **368** between upper wing **312** and upper shell **306**. Pivot connection **368** preferably includes a pivot pin **370** that engages apertures in upper wing **312** and surfaces in shell **306** to provide an axis of rotation between those components. As will be apparent to those skilled in the art, this pivoting motion may be used to provide a controlled, vertical range of motion between shell **306** and lower plate **304** of mouse assembly **300**, thereby facilitating the well-known "mouse click" movement, with the electrical functionality of the mouse click provided by conventional circuitry within mouse assembly **300**.

Upper wing **312** includes a pair of downwardly extending arms **372**, **374** that end in generally longitudinally extending supports **380**, **382** attached to the lower extent of "lateral" flexure assemblies, indicated generally at **384** and **386**. In this example, flexure assemblies **384**, **386** are constructed essentially identically to flexure assemblies **330** and **332**. Each flexure assembly **384**, **386** includes a respective flex band **388**, **390** which extends between a respective pair of support bars **360** and **380**, and **362** and **382**, and is secured thereto by mounting bars **356***a*, **356***b*, **356***c*, **356***d*. As will be apparent from the discussion above, flexure assemblies **384**, **386** will generally resist movement other than along a generally lateral axis extending generally perpendicular to longitudinal axis **344**.

Referring now primarily to FIG. **3**, therein is shown that when force sensor assembly **302** is assembled within mouse assembly **300**, it will be at least partially maintained in orientation within the mouse assembly by engagement between force sensor assembly **302** and lower support plate **304**. That engagement may be made through use of screws or any other suitable attachment mechanism.

Additionally, it can be seen that any downward pressure applied to mouse assembly **300** may be applied from the upper shell **306** through the three wings of force sensor **302**. The structure described above has each wing coupled to the lower extent of a flexure assembly attached to the wing below it, which in turn, is then attached to the upper extent of the flexure assembly in question. This structure serves to cause downward or compressive force on mouse assembly **300** to be transmitted through force sensor **302** by placing each flexure assembly in tension, rather than compression. This provides increased stability within force sensor **302**, and also avoids possible damage that could occur, such as buckling, if the flex assemblies were placed in compression, rather than tension. While the principles described herein may be used with a force sensor in which the flexure assemblies would be placed in compression, the need for structure that can withstand that compression could complicate the design and configuration of those flexure assemblies. Accordingly, in at least some examples of the invention utilizing a flexure assembly including a flex band or other member, as depicted in these Figures, this placing of the flexure assemblies in tension in response to applied force is a desirable feature.

Referring now to FIG. **6**A, the figure depicts an example of an alternative design for a force sensor assembly, indicated generally at **600**. In contrast to force sensor assembly **302**, which generally restricts movement between structural members to either of two perpendicular axes, force sensor assembly **600** allows 360 degrees of movement of a first structural member relative to a second structural member. In force sensor assembly **600**, although the movement is allowed to occur freely, the measurement of the movement will be determined through reference to measurements along two axes, such as through capacitance-based position sensors, as discussed previously.

Force sensor **600** includes a support platform **602**, serving as a relatively stationary, or reference, structural member. A central pillar **604** extends from support platform **602** and supports an upper platform **606**. Upper platform **606** is used to suspend a floating platform **608**. Floating platform **608** may be suspended by any sufficiently flexible mechanism that will allow deflection of floating platform **608** relative to support platform **602**, preferably through 360 degrees of movement, as discussed above. In one embodiment, a plurality of flexible strands or cables **610** are used as suspension members to suspend floating platform **608**. Such strands or cables may be secured in place by enlarged heads or other mechanisms, indicated generally at **622** for terminating such devices. The suspension members may be distributed in any pattern to provide even and flexible support. For example, placement of cables at four corners of a square upper platform **606**, or along perpendicular diameter lines of a circular platform, are examples that could be used.

As identified above, force sensor assembly **600** includes a first capacitance sensor indicated generally at **612**, and a second capacitance sensor indicated generally at **614** with the capacitance plate sensing pairs **616***a*, **616***b* and **618***a*, **618***b*, arranged in spaced relation relative to two orthogonal axes to measure deflection relative to the two axes. In this example, a first capacitance plate of each sensor is supported by lower plate **602**, and the other capacitance sensor plates **616***b*, **618***b* are each supported by floating platform **608**. The general structure and operation of capacitance sensors **612** and **614** is otherwise similar to that previously described. As shown in FIG. **6**B, a resistance mechanism **624**, such as an annular deformable member can be placed within aperture **620** in plate **608** (surrounding support pillar **604** to allow freedom of movement of floating platform **608**), so as to provide a resistance within force sensor assembly **600** to the deflection that results from a force acting on floating platform **608**. Such a resistance mechanism could be, for example, a silicon rubber sleeve.

As noted above, in some examples of input devices in which a force sensor as described and illustrated herein may be used, such as the computer mouse **300** identified in reference to FIG. **3**, the force sensor measurements will be used in combination with a speed measurement to provide an output indicating planar coordinates (X, Y) which may be used in a conventional manner to provide updated coordinates for a cursor relative to pixels on a display screen.

Referring now to FIG. **7**, therein is depicted a flowchart **700** graphically depicting this method of operation of an input device incorporating a force sensor constructed in accordance with the teachings herein. As will be apparent to those skilled in the art, some processing of the signals from such a force sensor, in combination with the signals from at least one other sensor, will be required to provide complete input device functionality. Although conceptually, much of this processing could be done within the processing system to which the input device will be attached, a preferred configuration is to perform at least a portion of the processing through one or more processors within the input device. Accordingly, it should be understood that the below-described method of operation may be performed entirely by processors within the input device, or may be performed, at least in part through a processor within the processing system to which the input device is attached. Each such processor will have appropriate signal inputs, and will include some machine-readable media. In most cases, the processors will also be operatively coupled to additional machine-readable media. Such machine-readable media will preferably be in the form of some form of solid-state memory, as may be formed using electrical, optical or magnetic, or any other type of information storage mechanism, suitable for temporarily or relatively permanently storing information for access by a machine. The term "machine-readable media" as used herein is expressly includes both single and plural instances of any such storage mechanisms. Although those skilled in the art will recognize many possible configurations for devices for performing the processing functionality, one example configuration is seen in FIG. **3**, wherein a processing module **358** is depicted. Processing module **358** may be relatively simple, including one or more processors, any external machine-readable media, and any additional required components contained on a printed circuit board, as depicted.

As discussed above, the force sensor will yield at least two, and possibly more, measurements of deflection. Where only two measurements are used, the most straightforward configurations will have those measurements along orthogonally arranged (X-Y) axes. Accordingly, using this simple case, the algorithm begins with receiving the X direction deflection signal **702**, and receiving the Y direction deflection signal **704** from the deflection sensors, such as the described capacitance sensors of mouse **300**. The act of receiving the signals from the deflection sensors includes any desired processing of those deflection signals. For example, in the case of capacitance measurement signals, it will often be desirable to filter or otherwise smooth the output signals. Additionally, depending upon the desired configuration for performing further operations with the signals, it may be preferable to digitize those signals for further processing. Other types of processing are, of course, possible. After the signals have been received and processed as desired, the signals may be combined in a conventional manner to yield a directional vector **706**, the directional vector representing the direction of the lateral, or planar, movement of the input device along the support surface.

As noted earlier herein, the directional information from the force sensor will be combined with another measurement, such as a speed signal, which will be received in the algorithm **708**, been processed any further matter desired. One preferred mechanism for generation of that speed signal is a vibration sensor. In such a system, the vibration signal from the sensor may be analyzed, for example to determine the number of signal spikes within a predetermined time interval (or alternatively, the number of zero crossings) to generate a vibration frequency measurement. Where such measurements are made in response to a time interval, an interval such as approximately 8 ms (or a sample rate of approximately 125 Hz), may conveniently be used. Alternatively, a portion of the vibration response spectrum, representing a response during a selected time interval, may be modeled in subjected to a Fourier transformation to provide an estimate of the speed. Additional explanations of various methods for determining speed of an input device from vibration measurements may be found in U.S. patent application Ser. No. 12/235,326, filed Sep. 22, 2008, and entitled "Using Vibration to Determine the Motion of an Input Device;" and U.S. patent application Ser. No. 12/182,799, filed Jul. 30, 2008, and entitled "Velocity Stabilization for Accelerometer Based Input Devices;" each of which is assigned to the assignee of the present application; and each of which is incorporated herein by reference for all purposes.

The speed signal and the direction vector will then be used to determine a positioning signal **710**, and then to generate a position signal output **712**. The position signal may, for example, include incremental input device coordinates ($\Delta X$, $\Delta Y$) which are then processed in a conventional manner to provide updated coordinates for a cursor relative to pixels on a display screen. The signal output may then be communicated through a conventional connection, such as may be provided through a USB link, to the processing system with which the input device is being used. The processing system will then typically implement suitable drivers to translate incremental input device coordinates ($\Delta X$, $\Delta Y$) and/or any other portions of the position signal output into incremental movement along pixels of the display device.

An alternative implementation of a processing algorithm may be used wherein no direction vector is directly determined, but wherein the X and Y deflection signals are combined directly with the speed signal to generate a positioning signal. For example, one way of performing such combination is to multiply each of the X and Y deflection signals by the magnitude of the speed measurement, to generate the incremental input device coordinates ($\Delta X$, $\Delta Y$).

There are many additional alternative constructions that may be envisioned to those skilled in the art having the benefit of the teachings of this disclosure. For example, force sensor assembly **300** of FIGS. **3-5** depicts flexure elements achieved through flex bands, which deflect in response to applied force, and then return to essentially their original position and state. Force sensor assembly **600** of FIG. **6** depicts a flexible member which suspends a structural member through flexible elements to facilitate the necessary displacement in response to applied force. However, alternative flexible yet resilient interconnections may be envisioned. For example, FIG. **8** depicts a connection **800** as might be implemented between two structural members **802**, **804** through placement of a resilient elastomeric element **806** between the two members. Such elastomeric element could be formed, as just one example, by a resilient silicone compound. In the depicted connection **800**, the structural members are configured with complementary extending lips **808**, **810** that embrace opposite sides of elastomeric element **806**. However, where elastomeric element **806** would be formed through a material that either had adhesive properties or could be used in combination with an appropriate adhesive, such lips would not be required; and a resilient connection could be established just through just the adhesive coupling between the two structural members, conceivably between purely planar portions of such structural members.

Many additional modifications and variations may be made in the techniques and structures described and illustrated herein. For example, for any of the described force sensor assemblies, even those restricted to motion that is generally restricted to just two axes, it could be desirable to use additional deflection measurement sensors. For example, depending upon the ability of the input device exterior components (such as base **302** and outer shell **304** of FIG. **3**), to resist uneven deflection, such as yaw (rotating relative to a vertical axis extending through the input device), it could be desirable to have an additional pair of deflection sensors proximate opposite ends of the force sensor assembly. In such configuration, the measurements from the sensors can be averaged or otherwise referenced with one another to optimize the accuracy of the measurement in the direction to which the sensors are responsive to an applied force. Additionally, a speed signal could be generated by alternative structures, including mechanical contact sensors, optical sensors, etc. Additionally, other systems than the capacitance sensors described herein may be used for determining the relative movement between components. Examples of systems that could be used in place of electrically-based systems are distance sensing mechanisms based on light (such as laser systems), sound (such as ultrasonic sensors), or pressure (such as piezoelectric systems). Accordingly the scope of the invention should be expressly understood to be limited only by the scope of the claims that are supported by the present specification, as well as all equivalents of such claims.

We claim:

**1**. An input device for a processing system, comprising:

a first support member;

a second support member;

a deflection member coupling the first support member and the second support member in movable relation, thereby permitting movement of the first and second support members in a direction perpendicular to the coupling;

a first sensor coupled at least in part to the deflection member and arranged to provide a signal representative of a magnitude of movement of the second support member relative to the first support member in a first area;

a second sensor coupled at least in part to the deflection member and arranged to provide a signal representative of the magnitude of the movement of the second support member relative to the first support member in a second area; and a resistance member that resists movement of the second support member permitted by the deflection member without moveably coupling the first support member and the second support member.

**2**. The input device for a processing system of claim **1**, further comprising a reference member, and wherein the second support member is further coupled in movable relation to the reference member.

**3**. The input device for a processing system of claim **2**, wherein each of the first and second force sensors is further coupled in part to at least one of the reference member and the second support member.

**4**. The input device for a processing system of claim **1**, further comprising a resilient component coupled proximate the first support member.

**5**. The input device for a processing system of claim **1**, further comprising an upper support element, and wherein the deflection member is suspended from the upper support element.

**6**. The input device for a processing system of claim **1**, wherein the deflection member includes at least one of a flexible elastomer, a flexible metal, or a flexible plastic.

**7**. The input device for a processing system of claim **6**, wherein the deflection member includes the flexible elastomer and the flexible elastomer comprises a silicon-based elastomer.

**8**. The input device for a processing system of claim **1**, wherein at least one of the first support member or the second support member comprises at least one of a rigid glass-filled plastic or a rigid metal.

**9**. The input device for a processing system of claim **1**, wherein the resistance member comprises silicon rubber.

**10**. The input device for a processing system of claim **1**, wherein the input device comprises at least one of a computer mouse or a hand-operated input device.

**11**. A method of constructing an input device for a processing system, comprising the acts of:

securing a first support member and a second support member in deflectable engagement with one another, where such deflectable engagement allows relative movement between the first support member and the second support member in a direction perpendicular to the deflectable engagement;

placing a resistance member that resists movement of the second support member allowed by the deflectable engagement without moveably coupling the first support member and the second support member;

arranging at least a first distance sensor proximate the first and second support members, the first distance sensor configured to provide a signal representative of a magnitude of any deflection between the first and second support members in a first area;

arranging the first and second support members and the first distance sensor within an outer housing of the input device, the housing comprising at least two component parts; and

arranging at least a second distance sensor proximate the first and second support members, the second distance sensor configured to provide a signal representative of the magnitude of any deflection between the first and second support members in a second area.

**12**. The method of constructing an input device for a processing system of claim **11**, wherein the act of securing the first support member and the second support member in deflectable engagement with one another comprises coupling the first and second support members to one another through a first metallic flex band at a first location and a second metallic flex band at a second location.

**13**. The method of constructing an input device for a processing system of claim **11**, wherein the act of securing the first support member and the second support member in deflectable engagement with one another comprises coupling a deformable member between the first and second support members.

**14**. The method of constructing an input device for a processing system of claim **11**, wherein the resistance to such relative movement is provided by a resistance member comprising silicon rubber.

**15**. The method of constructing an input device for a processing system of claim **11**, wherein once the housing is assembled from the at least two component parts, the housing does not have any openings through which mechanical or optical communication is established to the environment outside the input device.

**16**. The method of constructing an input device for a processing system of claim **11**, further comprising the acts of:

securing in the input device a speed sensor configured to provide a signal representative of speed of movement of the input device;

securing in the input device at least one processor and at least one machine-readable storage media bearing instructions that when executed by the at least one processor, perform operations comprising:

processing signals from the first and second distance sensors,

processing the signal from the speed sensor; and

generating a signal representative of movement of the input device within a plane in response to the signals.

**17**. The method of constructing an input device for a processing system of claim **11**, wherein the input device comprises at least one of a computer mouse or a hand-operated input device.

**18**. The method of constructing an input device for a processing system of claim **11**, wherein at least one of the first support member or the second support member comprises at least one of a rigid glass-filled plastic or a rigid metal.

**19**. The method of constructing an input device for a processing system of claim **11**, wherein said operation of securing a first support member and a second support member in deflectable engagement with one another comprises securing the first support member and the second support member utilizing at least one of a flexible elastomer, a flexible metal, or a flexible plastic.

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